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**HYBRID POWER UNIT**

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HYBRID POWER UNIT

[Groupe moto propulseur hybride]

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This invention concerns a hybrid power unit in which the electric machine is used to regulate the temperature of the exhaust gases in a treatment device for exhaust gases. /

In particular, the invention pertains to a power unit for an automobile, of the type having an internal combustion engine capable of driving at least one drive wheel of the vehicle and an electric machine that can be used in generator mode or propulsion mode, in which it participates in the driving of the vehicle, of the type in which, for certain operational states of the internal combustion engine, the engine is supplied with a so-called lean mixture of air/fuel in which the air is in excess with respect to the fuel, and of the type in which the internal combustion engine includes an exhaust system equipped with a treatment device for the exhaust gases.

In particular, the invention will be described in the context of a particular hybrid power unit. This power unit is made up of an internal combustion engine equipped with an electric

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\* [Numbers in the right margin indicate pagination of the foreign text.]

machine integrated with the flywheel. In a unit of this kind, the electric machine can deliver only a very small part of the maximum power of the heat engine, which then remains the principal source of the vehicle's engine power. The machine is connected to the flywheel of the heat engine, which means that the flywheel is actually made up essentially of the rotor of the electric machine. Therefore, the latter is linked directly to the drive shaft of the heat engine, and it is generally interposed between the heat engine and a transmission element such as a gear box. /

In this context, the electric machine is generally a machine that can be used in either motor mode or generating mode. In generating mode, the electrical machine then replaces the alternator to provide electric current to be used in the electrical system of the vehicle or to be stored in a storage battery. On the other hand, in motor mode, the electrical machine is supplied by current that was previously stored in the storage battery, and it provides a motor torque on the drive shaft, this motor torque being added to that of the heat engine to be transmitted to the vehicle's drive wheels.

The currently known method is to use the electrical machine in motor mode to start the heat engine, to reduce the acyclic motion of the heat engine when this engine operates in slow motion, or to provide briefly a torque supplement that will, for example, facilitate starting on an incline or passing another vehicle.

However, the invention is not in any way limited to such a power unit, and therefore may be applied in all cases of hybrid motorization in which the heat engine is capable of driving the vehicle on its own.

The invention is intended to apply to power units in which the internal combustion engine is able to operate on a lean mixture. When the engine operates on a lean mixture and when the driver's torque demand is not too great, fuel savings are possible. However, in a combustion engine where the exhaust gases must be cleaned, running on a lean mixture causes formation of nitrogen oxides (NO<sub>x</sub>), molecules that cannot subsequently be reduced in a standard catalysis device because the exhaust gases form an oxidizing medium. /

Thus, to prevent these nitrogen oxides from being discharged into the atmosphere, the standard practice is to store them in a storage device that is also called a NO<sub>x</sub> trap.

By using this NO<sub>x</sub> storage device, the molecules of NO<sub>x</sub> produced can be stored when the motor is running on a lean mixture, provided that the temperature of the device is within a certain temperature range, for example, between 250 and 450°C. On the other hand, when the engine is supplied with a rich fuel mixture, with an excess of fuel in relation to air, the exhaust gases become reducing, which permits reduction of the nitrogen oxides, NO<sub>x</sub>, and which allows the NO<sub>x</sub> trap to be emptied so that the engine can again run on a lean mixture.

Furthermore, it has appeared that NO<sub>x</sub> traps can not only store the nitrogen oxides, NO<sub>x</sub>, but they can also store sulfur oxides (SO<sub>x</sub>). If sulfur oxides can be stored at the same

temperatures at which nitrogen oxides are stored and empties out, then the sulfur oxides can be emptied only when the exhaust gases form a reducing medium and when the temperature of the storage device is higher than a certain level, for example higher than 650°C.

Thus, in order for the NOx trap to play its part effectively, it must be purged occasionally to release the sulfur oxides.

It is clear that, for complete cleaning of the exhaust gases, the temperature of the NOx storage device must be controlled. The temperature of this device depends essentially on the temperature and flow of the exhaust gases flowing through it.

Therefore, to control the temperature of the NOx storage device, the temperature of the exhaust gases must be controlled.

The temperature of the exhaust gases depends essentially on the engine's charge, which is the quantity of fuel injected into the cylinder in each cycle. However, manipulating engine charge is not enough to vary the temperature, because the charge also determined the torque delivered, and this parameter is the most important one, because it must be constantly adjusted to correspond as closely as possible to the driver's torque demand, for example when the driver steps on the accelerator pedal.

Thus the prior art recommends changing the temperature of the exhaust gases without changing the torque provided by the engine, specifically by making use of the angle of advance.

Modifying the angle of advance significantly changes the energy output of the engine, and in order to raise the temperature of the exhaust gases the angle of advance must be changed in a direction such that the output is thereby diminished. Thus, for the engine to provide the torque demanded by the driver, a larger amount of fuel will be required to the detriment of the vehicle's consumption.

For this reason, the object of the invention is a new concept of a power unit of the type described above, wherein the heat engine and the electrical machine are controlled in such a way that they respond continuously to promptings from the driver with a low fuel consumption and continuously permit perfect cleaning of the exhaust gases.

For this reason, the invention proposes a power unit of the type described above, characterized in that for certain operational states of the power unit, the mode of use of the electrical machine is determined by a control unit of the power unit to maintain the temperature of the exhaust gases in the treatment device within a determined temperature range.

According to other characteristics of the invention:

- the treatment device is a device for storage of the nitrogen oxide molecules present in the exhaust gases;
- for some operational states of the power unit, the heat engine being supplied with a lean mixture, and the torque demand becoming greater at a threshold value for which the temperature

of the nitrogen oxide storage device becomes higher than a maximum storage temperature, the control unit of the power unit controls the electrical machine in its motor mode to provide a motor torque to meet the torque demand so that the temperature of the exhaust gases will remain within a range of temperatures permitting storage of the nitrogen oxides while providing the combustion engine with a lean mixture;

-the combustion engine is equipped with a direct fuel injection system into the cylinder. By means of this system, for certain operational states of the engine, this engine is supplied with a stratified air-fuel mixture in which the distribution of the fuel in the cylinder is not homogeneous and in that, for certain operational states of the power unit, the heat engine being supplied with a stratified lean mixture, and the torque demand becoming greater than a threshold value for which the temperature of the nitrogen oxide storage device becomes higher than a maximum storage temperature, the control unit of the power unit controls the electrical machine in its motor mode to provide a motor torque that meets the torque demand, in order to maintain the temperature of the exhaust gases in a range of temperatures permitting storage of the nitrogen oxides, while supplying the combustion engine with a stratified mixture;

-for certain operational states of the engine, to maintain the temperature of the nitrogen oxide storage device above a minimum temperature, the control unit controls the electrical machine in its generating mode to provide a resistant torque that opposes the motor torque provided by the combustion engine, the latter being controlled to provide a torque equal to the sum of the torque demanded by the driver with the resistant torque of the electrical machine to raise the temperature of the exhaust gases;

-the electrical machine is controlled in its generating mode to maintain the temperature of the nitrogen oxide storage device in a range of temperatures permitting purging of the sulfur oxides contained in the nitrogen oxide storage device;

-the electrical machine is controlled in its generating mode to maintain the temperature of the nitrogen oxide storage device in a temperature range permitting the storage and emptying of nitrogen oxides;

-the combustion engine is a direct injection engine;

-the electrical machine is an integral part of the flywheel of the combustion engine;

-the combustion engine is a spark ignition engine.

Other characteristics and advantages of the invention will become apparent with a reading of the detailed description below. It is also clarified by the attached illustrations, in which:

-Figure 1 is a schematic view illustrating a power unit according to the invention;

-Figures 2A to 2D are graphs illustrating the operation of an engine representing the state of the art;

-Figures 3A to 3D are graphs illustrating, under the same conditions, the operation of a power unit according to the invention, enhanced to limit fuel consumption and pollution;

-Figure 4 is a flow chart illustrating the principal stages of a first process for controlling a power unit integrating the teachings of the invention;

-Figures 5A to 5D are graphs illustrating the control of a state of the art control unit when the temperature of the exhaust gases are to be raised to permit purging of the sulfur oxides, SOx; /

-Figures 6A to 6D are graphs illustrating the control of an engine according to the invention to permit emptying of the sulfur oxides retained in the storage device, and

-Figure 7 is a flow chart illustrating the principal stages of a second control process of a control unit according to the invention to operate the purge function.

Figure 1 is a schematic representation of a hybrid power unit 10, particularly a power unit 10 made up of a heat engine 12, for example an internal combustion engine with alternating pistons, equipped with an electrical machine 14 forming an integral part of its flywheel. The rotor 16 of the electrical machine 14 forms a single piece in rotation of the drive shaft 18 of the heat engine 12 so that the electrical machine 14 is interposed between the heat engine 12 and a transmission element 20 that can be, for example, a gear box equipped with a clutch.

A central control unit 22 controls the operation of the heat engine 12 and the electrical machine 14 as a function of a number of parameters, particularly as a function of a torque  $C_d$  demanded by the driver.

The vehicle's driver manifests the torque demand by operating an interface element such as an accelerator pedal.

The heat engine 12 provides a motor torque  $C_{mot}$  while the electrical machine 14 imposes on the drive shaft  $C_{me}$  which is positive when the electrical machine is used in its motor capacity and which is negative when the electrical machine is used in its generating capacity. / Thus, the power unit 10 provides the transmission device with a torque  $C_{gmp}$  which is equal to the algebraic sum of the torques  $C_{mot}$  and  $C_{me}$ .

When it is used in its generating capacity, the electrical machine 14, of which the rotor 16 is then rotated by the drive shaft 18 or by the transmission 20, produces current that can be used by an electrical system of the vehicle or can be stored in a storage battery.

According to the teachings of the invention, the heat engine 12 is an engine that can operate with a lean mixture, which is a fuel mixture in which the air is in excess with respect to the quantity of fuel. Of course, the engine is used in a lean mixture only for relatively low charges, with relatively low torque demands from the driver, and the maximum power of the engine can be obtained only with a mixture composition greater than or equal to a unitary mixture composition, or when the fuel mixture presents an excess of fuel compared with the stoichiometric equilibrium of the combustion reaction.

In the preferred mode of embodiment of the invention, the internal combustion engine 12 is an engine with spark ignition and direct fuel injection.

Direct fuel injection makes it possible to use particularly lean fuel mixtures, as ignition of the mixture is favored by the fact that the direct injection permits supplying the engine with a stratified lean charge, or a charge in which the fuel injected into the cylinder is not distributed homogeneously throughout the cylinder at the time of ignition, the fuel then being collected as much as possible in the vicinity of the spark plug to present a sufficient local concentration to initiate combustion. Compared to a homogeneous lean mixture, a stratified lean mixture can permit correct operation of the engine with even less fuel, to the benefit of the fuel consumption of the power unit.

According to the invention, the engine 12 is also provided with a system for cleaning exhaust gases. Traditionally, since it involves an engine with controlled ignition, it includes a three-way catalyst that can significantly reduce the hydrocarbon (HC), nitrogen oxide (NO<sub>x</sub>), and carbon monoxide (CO) content of the exhaust gases.

However, a three-way catalyst of this kind generally operates only for composition mixtures very close to unitary composition mixture, or only when the fuel mixture presents a stoichiometric ratio among the quantities of fuel of air introduced into the mixture for combustion. The stoichiometric ratio is essentially 1 g of fuel for 14.7 g of air.

Thus, to assure effective cleaning of the exhaust gases when the engine is used with a lean mixture, there is also a storage device for nitrogen oxides (NO<sub>x</sub>), also called an NO<sub>x</sub> trap. In fact, when the motor is supplied with a lean mixture, the emissions of hydrocarbons HC and carbon monoxide are very low, whereas the excess of oxygen tends to favor the formation of molecules of nitrogen oxides (NO<sub>x</sub>).

Therefore, when the motor is used with a lean mixture, the nitrogen oxides are stored in the storage device as they are produced. On the other hand, when the motor is supplied with a stoichiometric mixture or with a rich mixture, the molecules of nitrogen oxides obtained in the storage device can be emptied out.

According to a first aspect of the invention, the central control unit 22 of the power unit 10 will control the heat engine 12 and the electrical machine 14 in such a way that, when the engine runs on a lean mixture, the temperature of the exhaust gases is such that these gases maintain the storage device within a window of temperature between a low temperature T<sub>min</sub>, for example 250° and a high temperature T<sub>max</sub>, for example 450°. Within this temperature range, the reactions to storage and emptying of the NO<sub>x</sub> can take place.

Figures 2A and 2D illustrate a standard method for managing the temperature of the exhaust gases in the case of an engine running on a lean mixture.

Figure 2A illustrates the speed  $V$  of the vehicle as a function of time. In this case the driver wishes to accelerate the vehicle, this acceleration permitting passage of the vehicle from the speed  $V_1$ , equal to 70 km/h, for example, to speed  $V_2$ , equal to 100 km/h, for example, and this occurs between the times  $t_1$  and  $t_3$ . To perform this acceleration, therefore, it is necessary to control the heat engine 12 in such a way that it provides a torque supplement permitting this acceleration.

Figure 2B shows the temperature of the exhaust gases that would result from control of the heat engine if this engine were made to continue running on a lean mixture. It is clear that, up to time  $t_1$ , the engine is operated to maintain the vehicle at the speed  $V_1$  of 70 km/h and the temperature of these exhaust gases, in the NO<sub>x</sub> storage device, is equal, for example, to the temperature  $T_1$  of 400°C. This occurs in the storage window so that the storage operation can actually occur.

Then, starting from time  $t_1$ , the torque supplement demanded of the heat engine 12, still operated on a lean mixture, would bring about a rise in the temperature of the exhaust gases, and these gases during acceleration could reach a temperature equal to the temperature  $t_2$ , for example 500°C, i.e. higher than the temperature  $T_{\max}$  of nitrogen oxide storage. In fact, the curve shows that beyond the time  $t_2$ , the temperature of the exhaust gases would exceed 450°C.

Therefore, there is a threshold torque  $C_s$  which the heat engine cannot exceed when it is run on a lean mixture without the temperature of the exhaust gases exceeding a temperature for which the NO<sub>x</sub> storage device reaches a temperature higher than the maximum storage temperature, which is about 450°C. This torque  $C_s$  is lower than the maximum torque that the engine can supply on a lean system.

Thus, to avoid discharge of these nitrogen oxides into the atmosphere, Figure 2C, illustrates the mixture composition  $R$  of the fuel mixture supplied to the engine, shows that, starting from time  $t_2$ , the state of the art heat engine 12 must be run so that it is supplied with a stoichiometric fuel mixture to permit cleaning of the exhaust gases by the three-way catalyst. Such a fluctuation in the operation of the heat engine is detrimental to the engine's fuel consumption, partly because the motor's output is lower at the unitary mixture composition than with a lean mixture, and this is reinforced by the fact that the fluctuation of mode results in a transitory phase during which the engine's output is particularly poor.

Figure 2D illustrates the curve of temperature variation of the NO<sub>x</sub> storage device when the engine is operated according to the state of the art, as illustrated in Figure 2C. Therefore, it is clear that, starting at time  $t_2$ , during the fluctuation in stoichiometric mode, the temperature of the exhaust gases increases significantly in the storage device, still resulting in the same acceleration that permits the vehicle to go from 70 to 100 km/h. This time, the maximum temperature may reach 600°C, and this is also reinforced by the fact that, at unitary mixture



composition, CO and HC are burned in the NO<sub>x</sub> trap, resulting in a particularly exothermic reaction that contributes to the rise in temperature. As is shown on Figure 2D, this temperature rises extends well beyond the end of the acceleration period, and tends to maintain the temperature in the storage device above the maximum storage temperature of 450°C even though, as is clear particularly from Figure 2B, it would be possible theoretically to maintain the vehicle at its new speed V<sub>2</sub> while supplying the engine with a lean mixture and then obtaining a temperature T<sub>3</sub> of the exhaust gases in the storage device to about 430°; this temperature is compatible with the storage reaction.

Therefore, as shown in Figure 2C, the engine must be maintained in stoichiometric operation well beyond the time t<sub>4</sub> from which it might be feasible, cleaning problems aside, to run the engine again on a lean mixture to keep the vehicle at the speed V<sub>2</sub> of 100 km/h.

Figures 3A to 3D illustrate a mode of operating a power unit according to the invention that permits, during acceleration of the type just described, maintaining the heat engine 12 in operation on a lean mixture, of course without causing emission of nitrogen oxides into the atmosphere. The graphs of Figures 3A and 3B are identical to those of Figures 2A and 2B.

In the graph of Figure 3C, which illustrates the mode of use of the electric machine 14, it is clear that starting at time t<sub>2</sub> beyond which the torque demanded by the driver becomes greater than the threshold torque C<sub>s</sub> that the heat engine can supply without the temperature of the storage device exceeding the maximum temperature T<sub>max</sub> for storage of the NO<sub>x</sub>, the electric machine 14 is operated to function according to its motor mode, in which it supplies a motor torque to the drive wheels of the vehicle, using electrical energy that was previously stored in the storage battery.

Figure 3C illustrates a state of operation of the power unit 10 in which, outside of the acceleration period, the electrical machine is used as a generator, for example, to recharge the storage battery. However, for other states of operation of the engine, the electrical machine 14 could be at rest, or it could be used as a motor, depending on other operating parameters of the vehicle. The invention resides in the fact that one of the parameters according to which the control unit 22 operates the electrical machine 14 is, directly or indirectly, the temperature of the NO<sub>x</sub> storage device.

Consequently, Figure 3D shows that the temperature of the storage device remains within the range of temperatures for which the reactions of NO<sub>x</sub> storage are possible. In the same time, as shown in Figure 3A, the whole of the power unit 10 delivers a sufficient torque so that the vehicle accelerates as the driver wishes.

At time t<sub>3</sub>, when acceleration ceases and the torque demand is lowered, this is a level of torque demanded by the driver that is lower than the previously-defined threshold torque. It is now possible to gradually decrease the intervention of the electrical machine 14 so that the

vehicle is now driven only with the heat engine, the latter having received an uninterrupted supply of a lean mixture.

Thus, with the invention, we are able to avoid the fluctuation of the mode of operating the heat engine from a lean mixture to a stoichiometric mixture, to the benefit of the output and fuel consumption of the power unit.

To implement a process for operating a power unit according to the invention, therefore, the principal stages of the flow chart illustrated in Figure 4 can be followed. On this flow chart, at stage 100 we can verify first of all whether the torque demanded  $C_d$  is lower than the threshold torque  $C_s$  defined above. If it is, then the heat engine 12 need only be operated in such a way that it delivers this torque  $C_d$  demanded by the driver without the need to change the mode of operation, and the engine can run on a lean mixture.

Otherwise, in stage 110 we calculate the motor torque that must be supplied by the electrical machine 14. This torque  $C_{me}$  is equal to the difference in the torque  $C_d$  demanded by the driver, from which the threshold torque  $C_s$  is subtracted.

At stage 120 we can see, particularly as a function of the storage battery's charge, whether it is possible for the electrical machine to supply this torque.

If that is possible, the power unit 10 is run by the control unit 22 in such a way that the heat engine 12 supplies a torque equal to its threshold torque  $C_s$ , while the electrical machine 14 supplies the motor torque  $C_{me}$  calculated in stage 110. Thus, the power unit 10 supplies the vehicle with the total torque  $C_{gmp} = C_s + C_{me}$ , which is equal to the torque  $C_d$  demanded by the driver.

When, for example, the battery's charge does not permit the electrical machine 14 to supply sufficient torque, then it would be necessary, to meet the torque demand  $C_d$  without causing nitrogen oxide emission, to fluctuate the mode of engine operation, the heat engine 12 being supplied with a stoichiometric mixture and being operated to supply a motor torque  $C_{mot}$  equal to the torque demanded by the driver.

The above example describes a process for operating the power unit 10 which permits, in some cases, avoiding the fluctuation of the heat engine from one mode of operation on a lean mixture to a mode of operation on a homogeneous mixture.

However, in a heat engine with direct injection, the same operating strategy can be put into practice to avoid fluctuation of the heat engine from one mode of operation on a stratified lean mixture to a mode of operation on a homogeneous lean mixture to further improve the output of the power unit.

Another case of application of the invention is considered to carry out a purge of the sulfur oxides contained in the nitrogen oxide storage device.

In fact, such emptying of the sulfur oxides SOx can be performed only when the temperature in the storage device is higher than a threshold temperature  $T_s$ , for example equal to 650°C. Of course, such an operation of emptying the sulfur oxides, which results from a reduction reaction, can occur only when the exhaust gases form a reaction medium, i.e. only when the heat engine 12 is supplied with a fuel mixture with a composition equal at least to 1 or even higher.

However, when the engine is supplied with a stoichiometric mixture, it is rare for the exhaust gases to allow the storage device to reach such a temperature during normal vehicle operating conditions.

Thus, when the vehicle is rolling at a stabilized speed, for example at speed  $V_1$  of 100 km/h to obtain a rise in temperature without changing the torque supplied by the heat engine 12, in the state of the art the angle of advance of the engine 12 must be changed to lower its output. Thus, during the entire time interval of the purge between times  $t_1$  and  $t_2$ , the value  $A$  of the angle of advance is reduced, as shown in Figure 5B. At the same time, to compensate for the lowered yield, the angle of opening  $\alpha_{pap}$  of the air intake throttle is increased as shown in Figure 5C. Since the mixture composition is unitary, this necessarily corresponds to an increase in the quantity of fuel introduced into the cylinders in each cycle.

Accordingly, Figure 5D shows that by using this device it is possible to obtain an exhaust gas temperature that reaches the temperature  $T_s$  necessary for emptying of the sulfur dioxides, which is 650°C. However, by using this process according to the state of the art, it is clear that throughout the purge of the sulfur oxides the heat engine must be supplied with more fuel, although this is not made necessary by the driver's desire to accelerate or by the presence of an incline.

On the other hand, because of the process according to the invention, as shown in Figures 6A to 6D, the temperature of the exhaust gases will be raised. This will be done, as shown in Figure 6C, by the fact that the heat engine is supplied throughout this period with a quantity of fuel that makes this temperature increase possible.

However, because of the invention, the engine output need not be decreased to maintain a constant speed. In fact, according to the invention, the central control unit operates the electrical machine 14 in such a way that, throughout the purge, the machine 14 produces electrical current, which is to say that it acts as a generator. The electrical machine 14 then absorbs a torque, and the control unit 22 operates the machine 14 in such a way that the absorbed torque is equal to the excess torque supplied by the heat engine over the torque demanded by the driver.

Thus, unlike the state of the art, the rise in temperature that is obtained by burning a larger quantity of fuel is not lost because the additional energy supplied by this fuel is transformed into electrical energy, which is stored in the storage battery and can be used later.

As in this first example of embodiment of the invention, outside of the purge time the electrical machine 14 could be used in drive mode or could be at rest, depending on other operating parameters of the vehicle.

Figure 7 shows a flow chart illustrating the principal stages of a process whereby, according to the invention, the sulfur oxides contained in the nitrogen oxide storage device can be purged.

First of all, in stage 200, the control unit 22 of the power unit 10 operates the heat engine so that it is supplied with a fuel mixture in stoichiometric proportions, or at unitary mixture composition. Then, in stage 210, we verify whether the temperature  $T$  of the NOx storage device is higher than the minimum purge temperature  $T_s$  of the sulfur oxides, or about  $650^\circ$ .

If it is, and this may be the case with a large load when the driver demands a high level of torque, the central control unit leaves the electrical machine 14 at rest and operates the heat engine so that it supplies the entire torque  $C_d$  demanded by the driver.

Otherwise, if the temperature  $T$  of the NOx storage device is lower than the temperature  $T_s$  of  $650^\circ$ , at stage 220 we evaluate the value of the torque  $C_{me}$  that the electrical machine 14 should absorb so that the corresponding elevation of the torque supplied by the heat engine will be the cause of a sufficient rise in the temperature of the exhaust gases to arrive at the necessary temperature of the NOx storage device. Therefore, the torque  $C_{me}$  is a negative torque and in stage 200, particularly depending on the battery's charge, we verify whether it is actually possible for the electrical machine to absorb such a torque.

If it is, the heat engine is operated to supply the torque  $C_{mot}$  that is equal to the torque  $C_d$  demanded by the driver less the torque  $C_{me}$  supplied by the electrical machine 14, which is negative because the electrical machine 14 then absorbs power.

In stage 230, we verify whether the temperature  $T$  of the NOx storage device is indeed higher than the threshold level  $T_s$  of  $650^\circ$ . If so, the control unit 22 continues to operate the power unit 10 in this way until the purge of the sulfur oxide molecules is completed.

If the temperature of  $650^\circ$  is never reached, we then use a strategy of changing the angle of advance. By replacing the strategy defined above or complementing it, this modification makes it possible to increase the temperature of the exhaust gases, as described in the state of the art section.

In the second example of embodiment of the invention, we described a process for operating an engine in which the goal of the process was to keep the temperature of the nitrogen oxide storage device above the threshold level  $T_s$  for purge of sulfur oxides. Of course, this same process can be adapted to keep said temperature above the minimum temperature  $T_{min}$  for storage and emptying of the nitrogen oxides.

Similarly, the scope of the invention can be extended to any power unit in which the mode of operation of the electrical machine is determined by the operating temperature of a device of any kind for treatment of exhaust gases.

### Claims

1. Power unit for an automobile, of the type having an internal combustion engine (12), that can drive at least one drive wheel of the vehicle and an electrical machine (14) which can be used in a generating mode or a drive mode in which it participates in the drive of the vehicle, of the type in which, for some states of operation of the internal combustion engine (12), it is supplied with a so-called lean air/fuel mixture in which the air is in excess with respect to the fuel, and of the type in which the internal combustion engine (12) includes an exhaust system equipped with a device for treating exhaust gases,

characterized in that for some states of operation of the power unit (10), the mode of use of the electrical machine (14) is determined by a control unit (22) of the power unit to maintain a temperature of the exhaust gases in the treatment device in a determined temperature range.

2. Power unit according to Claim 1, characterized in that the treatment device is a device for storage of the molecules of nitrogen oxides present in the exhaust gases.

3. Power unit according to Claim 2, characterized in that, for some states of operation of the power unit, the heat engine (12) being supplied with a lean mixture, and the torque demand ( $C_d$ ) becoming greater than a threshold value ( $C_s$ ) for which the temperature of the nitrogen oxide storage device becomes higher than a maximum storage temperature ( $T_{max}$ ), the control unit of the power unit operates the electrical machine (14) in its drive mode to supply a drive torque ( $C_{me}$ ) to meet the torque demand ( $C_d$ ) in order to maintain the temperature of the exhaust gases in a temperature range that will permit storage of the nitrogen oxides while supplying the combustion engine (12) with a lean mixture.

4. Power unit according to Claim 3, characterized in that the combustion engine is provided with a system for direct injection of fuel into the cylinder whereby, for some states of operation of the engine, the engine is supplied with a stratified air/fuel mixture in which the distribution of the fuel in the cylinder is not homogeneous and in that, for some states of operation of the power unit, the heat engine (12) being supplied with a stratified lean mixture and the torque demand ( $C_d$ ) becoming greater than a threshold value ( $C_s$ ) for which the temperature of the device that stores nitrogen oxides becomes higher than a maximum storage temperature ( $T_{max}$ ), the control unit (22) of the power unit (10) operates the electrical machine (14) in its drive mode to supply a drive torque ( $C_{me}$ ) to meet the torque demand ( $C_d$ ) in order to maintain the temperature of the exhaust gases at a temperature permitting storage of the nitrogen oxides while supplying the combustion engine (12) with a stratified mixture.

5. Power unit according to Claim 2, characterized in that, for some states of operation of the engine, to keep the temperature of the nitrogen oxide storage device above a minimum temperature ( $T_s$ ), the control unit (22) operates the electrical machine (14) in its generator mode to supply a resistant torque ( $C_{me}$ ) opposing the drive torque supplied by the combustion engine (12), the latter being operated to supply a torque ( $C_{mot}$ ) equal to the sum of the torque ( $C_d$ ) demanded by the driver with the resistant torque ( $C_{me}$ ) of the electrical machine (14), to increase the temperature of the exhaust gases.

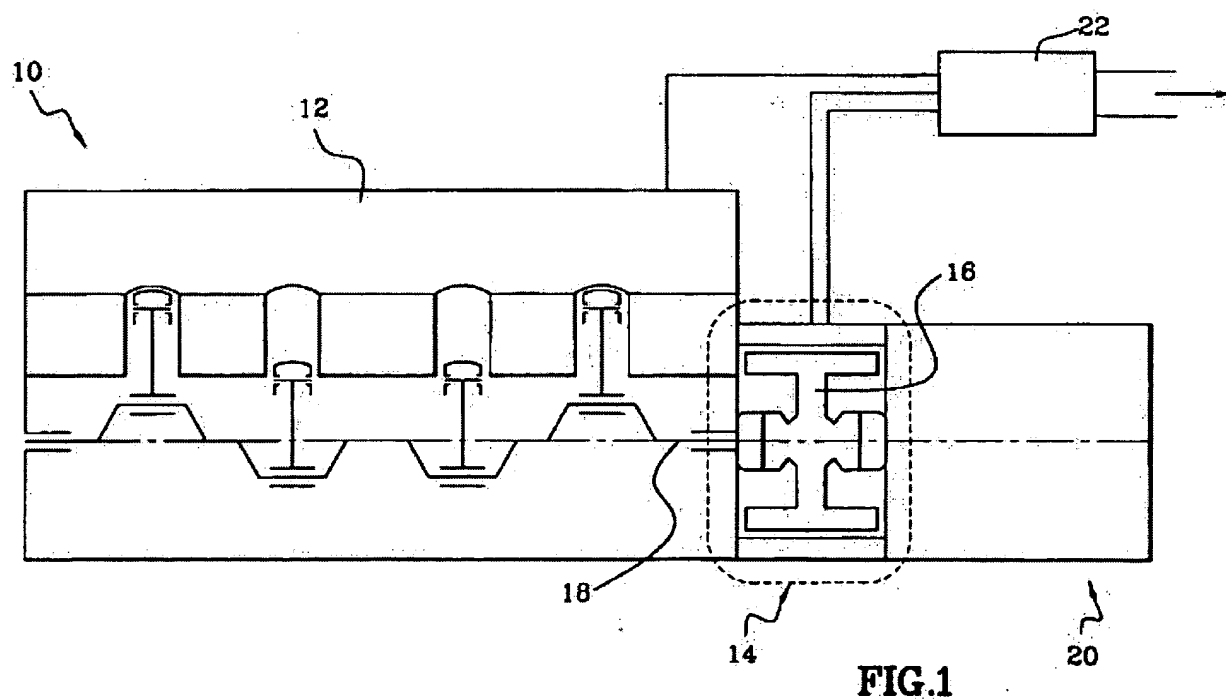
6. Power unit according to Claim 5, characterized in that the electrical machine (14) is operated in its generator mode to keep the temperature of the nitrogen oxide storage device in a temperature range permitting a purge of the sulfur oxides contained in the nitrogen oxide storage device.

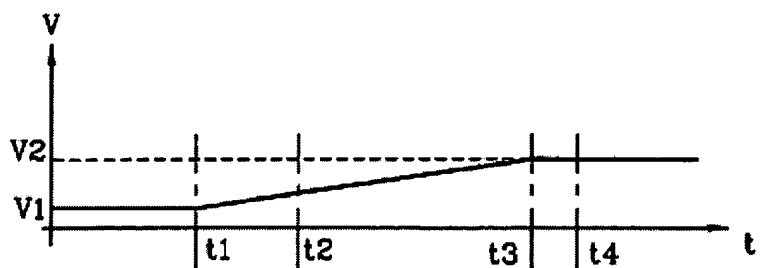
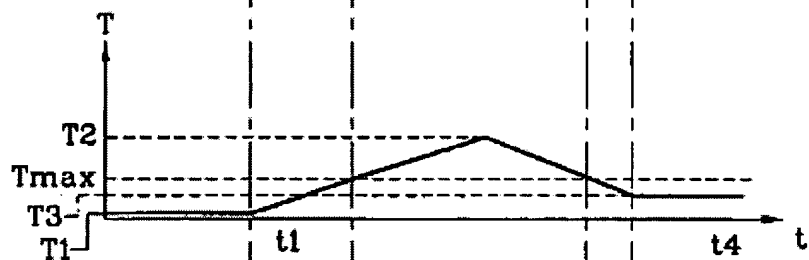
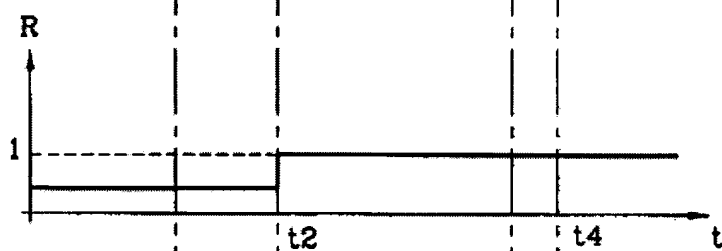
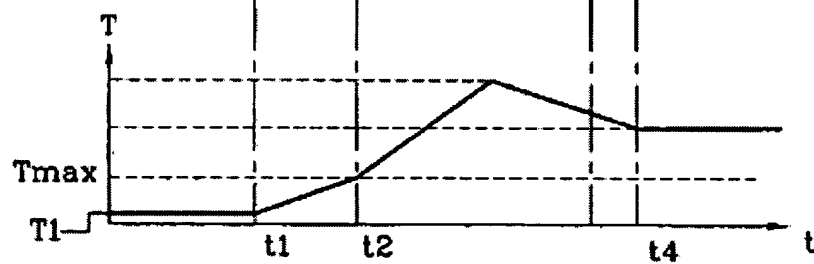
7. Power unit according to Claim 5, characterized in that the electrical machine is operated in its generator mode to keep the temperature of the nitrogen oxide storage device in a temperature range permitting the storage and emptying of the nitrogen oxides.

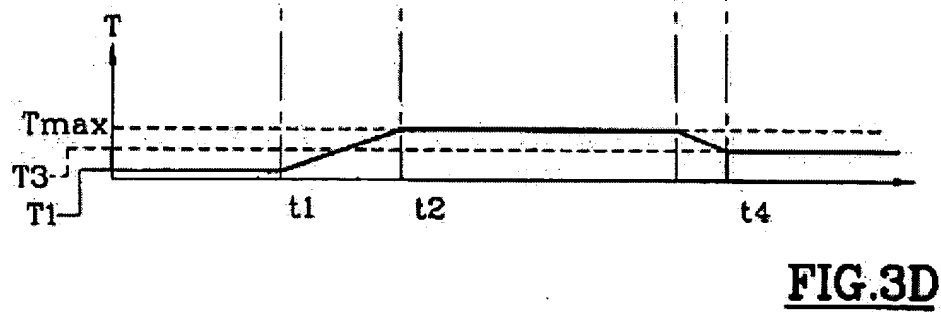
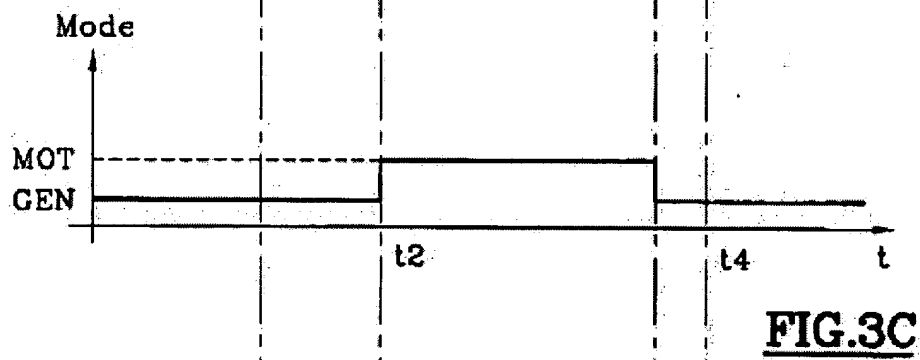
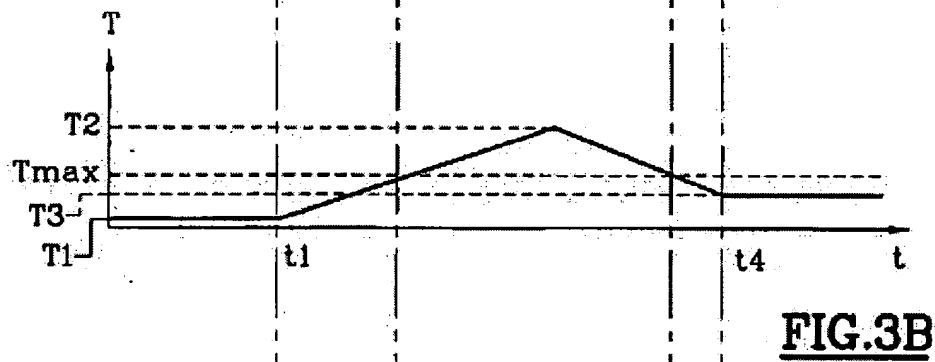
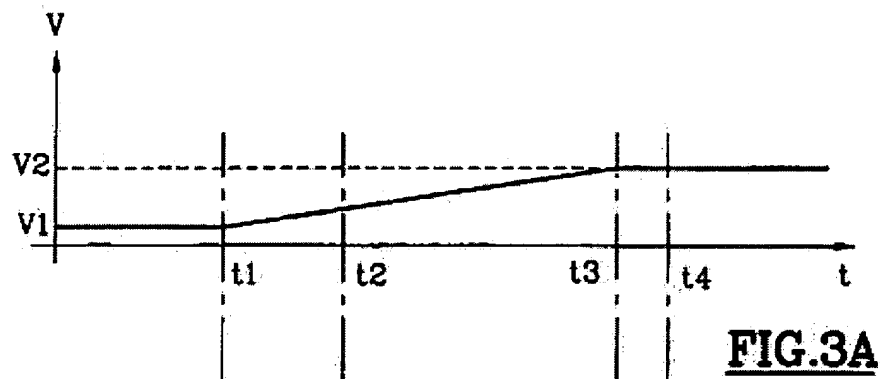
8. Power unit according to any of Claims 5 to 7, characterized in that the combustion engine (12) is a direct injection engine.

9. Power unit according to any of the preceding claims, characterized in that the electrical machine (14) is an integral part of the flywheel of the combustion engine (12).

10. Power unit according to any of the preceding claims, characterized in that the combustion engine (12) is a controlled ignition engine.

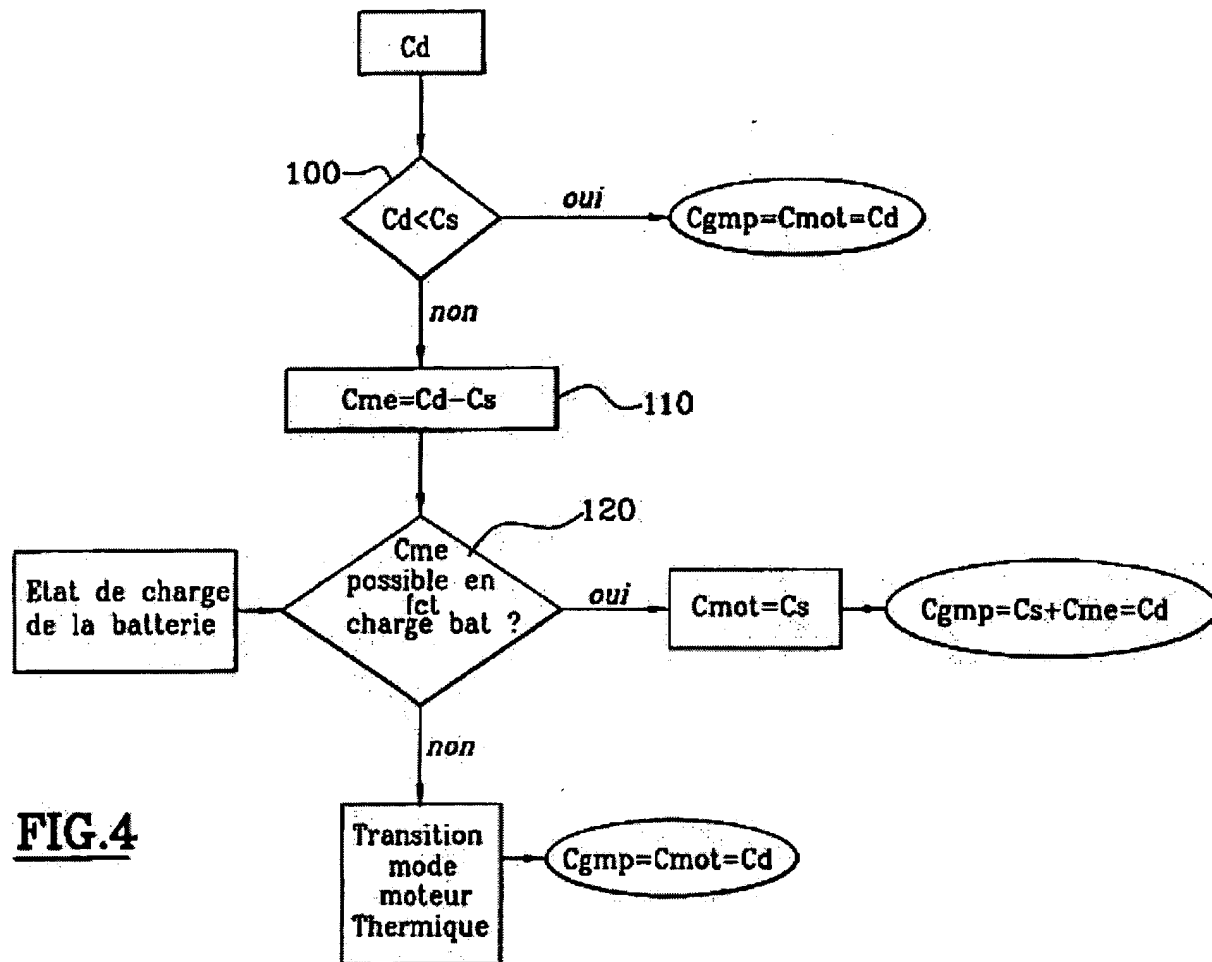


**FIG.2A****FIG.2B****FIG.2C****FIG.2D**

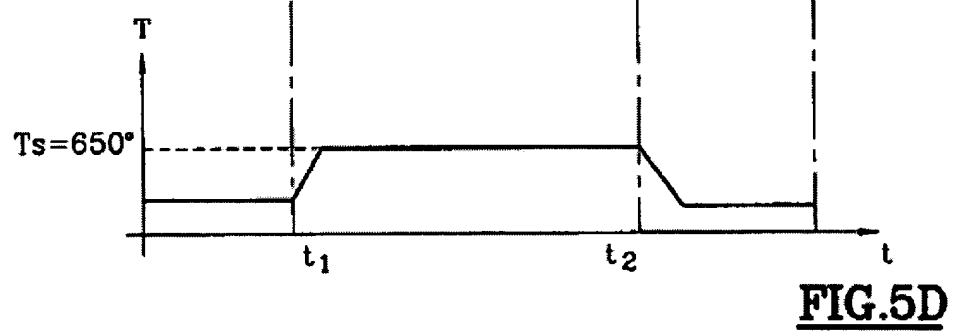
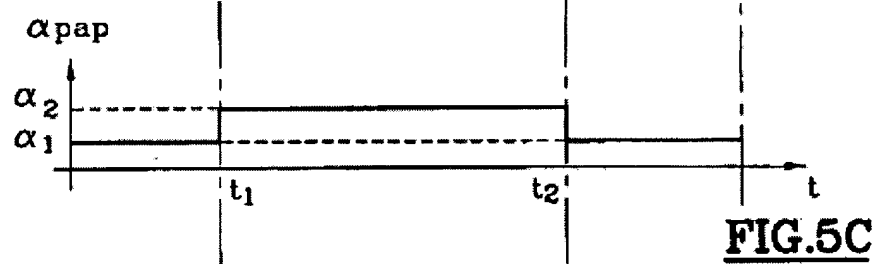
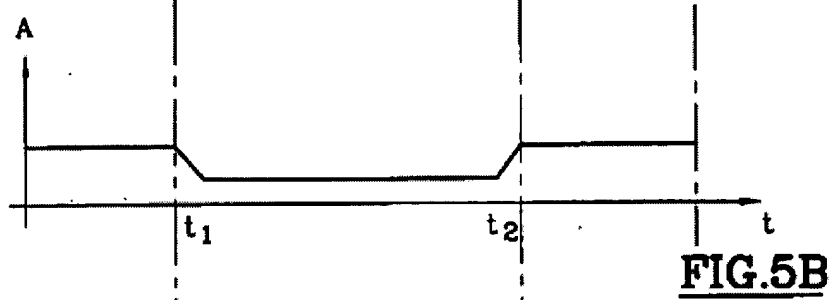
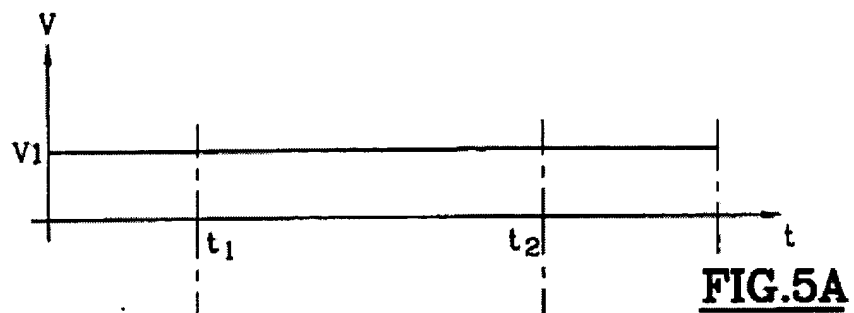


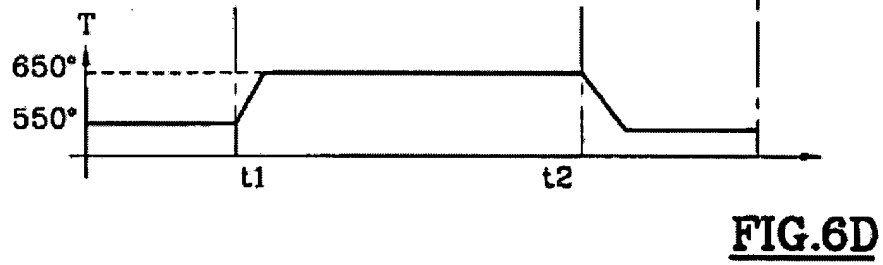
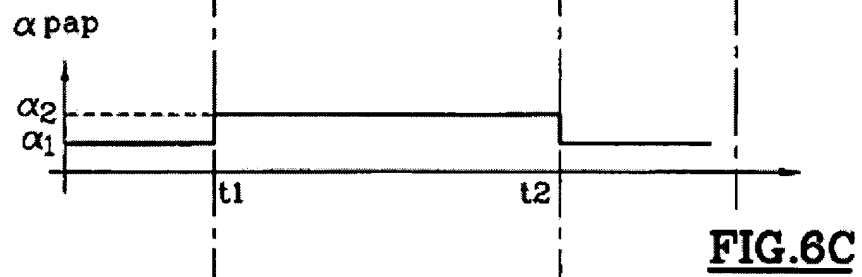
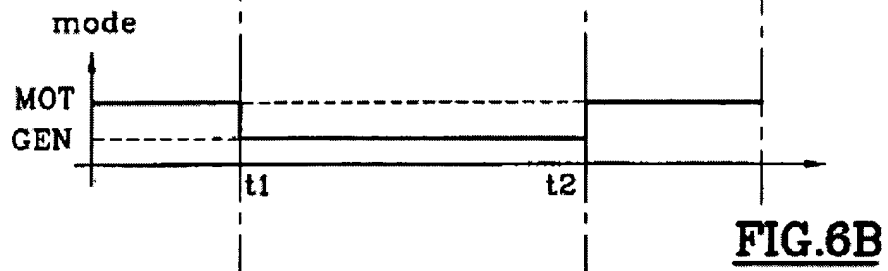
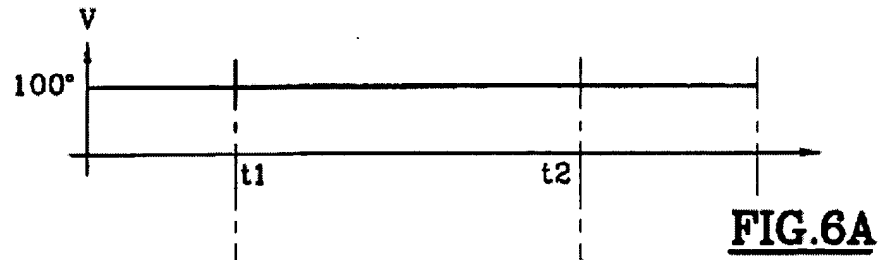
Key: 1 DRIVE  
2 GENERATOR

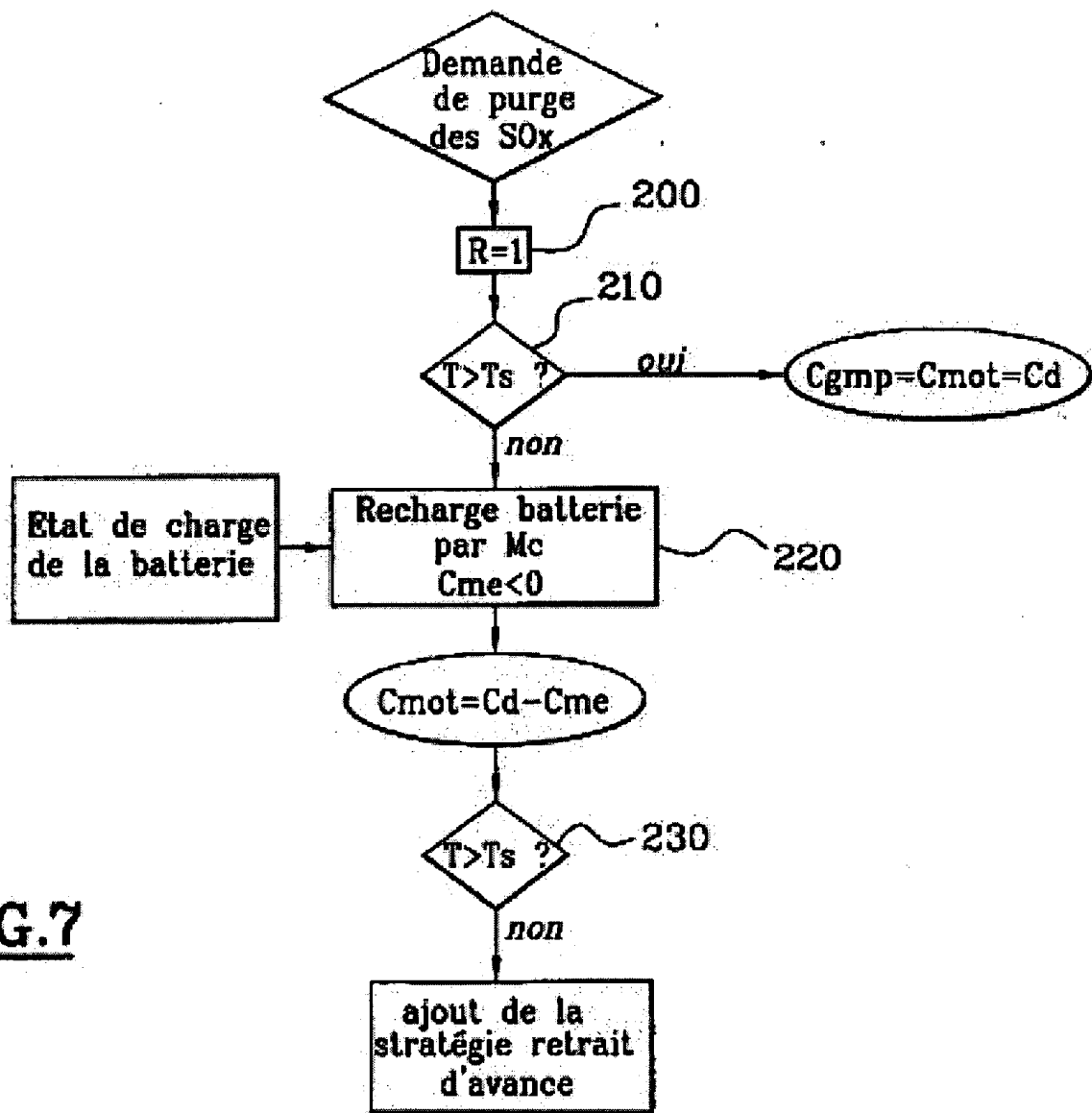




- Key:
- 1 Yes
  - 2 No
  - 3 State of battery charge
  - 4 Cme possible as a function of battery charge?
  - 5 Transition drive mode Heat







**FIG. 7**

- Key:
- 1     Demande for purge of SOx
  - 2     Yes
  - 3     No
  - 4     State of battery charge
  - 5     Recharge battery by Mc
  - 6     Addition of advance retreat strategy

FRENCH REPUBLIC  
National Institute  
of Industrial Property

Application Number  
FA 563359  
FR 9813001

### SEARCH REPORT

established on the basis of the most  
recent claims filed before the start of  
the search

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication where appropriate, of relevant passages	Claims concerned in the examined document	
A	EP 0 860 595 A (FORD GLOBAL TECH INC) August 26, 1998 * Summary; figure 1 * * column, 2, line 33-line 37 * ---	1,2,10	TECHNICAL FIELDS SEARCHED (Int. Cl. <sup>6</sup> )  B60K
A	US 5 343 970 A (SEVERINSKY ALEX J) September 6, 1994 * Summary figures 4, 9, 13 * column 12, line 13-line 21 ---	1,10	
A	WO 92 15778 A (FORD WERKE AG; FORED MOTOR CO (US); FORD FRANCE (FR); FORED MOTOR CO) September 17, 1992 * page 2, line 34 – part 3, line 20 * ---	1	
A	DE 196 18 865 A (FICHTEL & SACHS AG) November 13, 1997 * Summary; figure 2 * * column, 2, line 3-line 5 * -----	1,9	
Date of completion of the search June 16, 1999		Examiner Wagner, H	
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O: Non-written disclosure.		L: Document cited for other reasons.	
P: Intermediate document.		.....	
		&: Member of the same patent family, corresponding document.	